JC18 Rec'd PCT/PTO 13 JUN 2001

FORM PTO-1390 (Modified)
(REV 11-2000)

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER
783.1005

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR
09/868051

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/FI99/01028	**December 13, 1999**	**December 14, 1998**

TITLE OF INVENTION
METHOD AND APPARATUSES FOR DIGITAL IMAGING

APPLICANT(S) FOR DO/EO/US
Kustaa NYHOLM

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include itens (5), (6), (9) and (24) indicated below.
4. ☐ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   - a. ☒ is attached hereto (required only if not communicated by the International Bureau).
   - b. ☐ has been communicated by the International Bureau.
   - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   - a. ☐ is attached hereto.
   - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   - b. ☐ have been communicated by the International Bureau.
   - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☐ A copy of the International Search Report (PCT/ISA/210).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☒ Certificate of Mailing by Express Mail
23. ☒ Other items or information:

    Letter Re Priority
    Marked-Up Version of the Substitute Specification
    Un-Marked Version of the Substitute Specification
    Un-Marked Version of the Claims as Amended

JC18 Rec'd PCT/PTO 13 JUN 2001

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 09/868051	INTERNATIONAL APPLICATION NO. PCT/FI99/01028	ATTORNEY'S DOCKET NUMBER 783.1005

24. The following fees are submitted:.

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

		CALCULATIONS	PTO USE ONLY
☒ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO	**$1000.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO	**$860.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO	**$710.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4)	**$690.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4)	**$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =		**$1,000.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).		**$0.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	29 - 20 =	9	x $18.00	**$162.00**	
Independent claims	2 - 3 =	0	x $80.00	**$0.00**	
Multiple Dependent Claims **(check if applicable).**			☐	**$0.00**	
TOTAL OF ABOVE CALCULATIONS =				**$1,162.00**	
☐ Applicant claims small entity status. (See 37 CFR 1.27). The fees indicated above are reduced by 1/2.				**$0.00**	
SUBTOTAL =				**$1,162.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +				**$0.00**	
TOTAL NATIONAL FEE =				**$1,162.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).** ☐				**$0.00**	
TOTAL FEES ENCLOSED =				**$1,162.00**	
				Amount to be: refunded	$
				charged	$

a. ☒ A check in the amount of **$1,162.00** to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. ______ in the amount of ______ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **50-0518** A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

STEINBERG & RASKIN, P.C.
1140 Avenue of the Americas
15th Floor
New York, New York 10036-5803

By Pat J. Higgins Reg. 44,152

SIGNATURE

Martin G. Raskin

NAME

25,642

REGISTRATION NUMBER

June 13, 2001

DATE

09/868051

JC18 Rec'd PCT/PTO 13 JUN 2001

CERTIFICATE OF MAILING BY "EXPRESS MAIL" (37 CFR 1.10)	Docket No.
Applicant(s): Kustaa NYHOLM	783.1005

Serial No.	Filing Date	Examiner	Group Art Unit
N/Y/K	June 13, 2001	N/Y/K	N/Y/K

Invention: **METHOD AND APPARATUSES FOR DIGITAL IMAGING**

I hereby certify that the following correspondence:

New 371 filing based on a PCT application with associated documents and fee

(Identify type of correspondence)

is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 in an envelope addressed to: The Assistant Commissioner for Patents, Washington, D.C. 20231 on

June 13, 2001
(Date)

Annette McPherson
(Typed or Printed Name of Person Mailing Correspondence)

Annette McPherson
(Signature of Person Mailing Correspondence)

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P06A/REV02

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JC18 Rec'd PCT/PTO 13 JUN 2001

783.1005

UNITED STATES PATENT AND TRADEMARK OFFICE

Re:	Application of:	Kustaa NYHOLM
	Serial No.:	Not yet known
	Filed:	Simultaneously
	For:	**METHOD AND APPARATUSES FOR DIGITAL IMAGING**

PRELIMINARY AMENDMENT

Assistant Commissioner of Patents
Washington, D.C. 20231

June 13, 2001

Sir:

Prior to examination and calculation of the filing fee, please amend the above-identified application as follows:

IN THE SPECIFICATION:

Please substitute the original specification for the "Un-Marked Version of the Substitute Specification" enclosed herewith.

In addition, enclosed please find a "Marked-Up Version of the Substitute Specification" showing all of the amendments made to the original specification herein. Please note, additions to the specification are denoted by either underlining and/or hyphenating and deletions from the specification are denoted by bracketing.

IN THE CLAIMS:

Please amend the claims as follows:

1. (Amended) A digital imaging method, in which method the object being imaged is irradiated and the radiation is detected by means of semiconductor sensors, which comprise an active area, and in their three-dimensional structure an area or areas for control couplings, whereby the area covered by the semiconductor sensors is substantially smaller than the image-forming surface of the object being imaged, [characterized in that] said method comprising the steps of:

irradiating the object being imaged [is irradiated twice] a first time;

[and] moving the semiconductor sensors [are moved] to a new position [between the irradiations, in which case]; and

irradiating the object being imaged a second time, wherein the sensors are arranged to cover [the] an image-forming surface so that the entire image-forming surface can be imaged.

2. (Amended) An imaging method as claimed in claim 1, [characterized in that the] wherein a coupling area of the semiconductor sensor is arranged on one [of its sides] side of the semiconductor sensor.

3. (Amended) An imaging method as claimed in claim 1 [or 2, characterized in that] wherein the semiconductor sensors are arranged to form [a substantially] rectangular [bar] bars.

4. (Amended) An imaging method as claimed in claim 3, [characterized in that the said

bar is] <u>wherein said bars are</u> arranged to be formed of one column (1 x N) of semiconductor sensors.

5. (Amended) An imaging method as claimed in claim 4, [characterized in that] <u>wherein</u> the semiconductor sensors are arranged in the [bar] <u>bars</u> so that [their] <u>the</u> coupling areas [are] <u>of said semiconductor sensors</u> located [essentially] on one side of [the] <u>each</u> bar.

6. (Amended) An imaging method as claimed in [any of the claims 3 to 6, characterized in that] <u>claim 3, wherein</u> the bars are arranged to form a sensor matrix, [in which] <u>and wherein</u> the bars are arranged at a distance from one another so that the said distance between the bars is at most equal to the width of [the] <u>an</u> active area formed by the semiconductor sensors in the bars.

7. (Amended) An imaging method as claimed in claim 6, [characterized in that the] <u>wherein</u> outermost bars of the sensor matrix are arranged so that [their] <u>an</u> active area <u>of the outermost bars</u> comprises the outer edges of the image-forming surface.

8. (Amended) An imaging method as claimed in claim 3, [characterized in that the] <u>wherein</u> said [bar is] <u>bars are</u> arranged to comprise two columns (2 x N) of semiconductor sensors.

9. (Amended) An imaging method as claimed in claim 8, [characterized in that] <u>wherein</u> the semiconductor sensors are arranged in the [bar] <u>bars</u> so that [their] coupling areas <u>of the</u>

semiconductor sensors are located [essentially] on two sides of [the] each bar.

10. (Amended) An imaging method as claimed in claim 8 [or 9, characterized in that] wherein the bars are arranged to form a sensor matrix, [in which] and wherein the bars are arranged at a distance from one another so that the [said] distance is at most equal to the width of [the] an active area formed by the semiconductor sensors in the bars.

11. (Amended) An imaging method as claimed in [any of the claims 1 to 10, characterized in that] claim 1, further comprising the step of:

limiting the radiation [is limited essentially] to [the] an area covered by the sensors, for which limiting function a suitable collimator construction is [preferably] used.

12. (Amended) An imaging method as claimed in claim 11, [characterized in that] further comprising the step of:

separately moving the collimator construction and the sensors [are moved separately].

13. (Amended) An imaging method as claimed in [any of the claims 1 to 12, characterized in that] claim 11, wherein the movement of at least one of the collimator construction [and/or] and the sensors is carried out by means of solenoids.

14. (Amended) An imaging method as claimed in any of the claims 1 [to 13,

characterized in that] wherein CMOS sensors are used as the semiconductor sensors.

15. (Amended) An imaging method as claimed in [any of the claims 1 to 14, characterized in that] claim 1, wherein the method is used in the context of mammographic imaging.

16. (Amended) An apparatus for digital imaging, in which imaging a radiation source is used for irradiating [the] an object to be imaged and semiconductor sensors are used for detecting the radiation, [whereby the] said apparatus comprising:

semiconductor sensors (1) [comprise] having an active area (A), and in their three-dimensional structure, an area or areas for control couplings (K), the area covered by the said semiconductor sensors (1) being substantially smaller than the image-forming surface, [characterized in that the apparatus comprises] and

means for moving the semiconductor sensors (1) to a new position between two irradiations, in which apparatus the semiconductor sensors (1) and the means for moving [them] the semiconductor sensors are arranged so that the area covered by the semiconductor sensors (1) in their initial position prior to the move, combined with the area covered by the semiconductor sensors (1) in their position after the move, cover the entire image-forming surface.

17. (Amended) An apparatus as claimed in claim 16, [characterized in that] the [coupling] area for control couplings (K) of the semiconductor sensor (1) [is] are arranged on one [of its sides] side of the semiconductor sensor (1).

18. (Amended) An apparatus as claimed in claim 16 [or 17, characterized in that] wherein several semiconductor sensors (1n) are arranged to form [an essentially] rectangular [bar] bars (2).

19. (Amended) An apparatus as claimed in claim 18, [characterized in that] wherein the [said bar] bars (2) [comprises] comprise one column (1 x N) of semiconductor sensors (1n).

20. (Amended) An apparatus as claimed in claim 19, [characterized in that] wherein the semiconductor sensors (1n) are arranged in the [bar] bars (2) so that [their] the area of control coupling [areas] (K) [are essentially] is located on one side of [the] each bar (2).

Please add the following new claims.

21. (New) An apparatus as claimed in claim 18, wherein the bars (2) form a sensor matrix (3) in which the bars (2) are arranged at a distance (A#) from one another, in such a way that the distance (A#) is at most equal to the width of an active area (A) formed by the semiconductor sensors (1n) in the bars (2).

22. (New) An apparatus as claimed in claim 21, wherein the active area (A) of the outermost bars (2) of the sensor matrix (3) comprise the outer edges of the image-forming surface.

23. (New) An apparatus as claimed in claim 18, wherein the bars (2) comprise two columns (2 x N) of semiconductor sensors (1n).

24. (New) An apparatus as claimed in claim 23, wherein the semiconductor sensors (1n) are arranged in each bar (2) in such a way that the area for control coupling (K) for each semiconductor sensor (1n) is located on two sides of each bar (2).

25. (New) An apparatus as claimed in claim 23 wherein the bars (2) form a sensor matrix (3) in which the bars (2) are arranged at a distance (A#) from one another, in such a way that the distance (A#) is at most equal to the width of an active area (A) formed by the semiconductor sensors (1n) in the bars (2).

26. (New) An apparatus as claimed in claim 16, further comprising:

means for limiting radiation to an area covered by the semiconductor sensors (1), the means for limiting radiation comprising a suitable collimator construction (4, 5).

27. (New) An apparatus as claimed in claim 26, further comprising:

means for moving the collimator construction (4, 5), and

means for moving the semiconductor sensors (1).

28. (New) An apparatus as claimed in claim 27, wherein said means for moving at least one of the collimators (4, 5) and the sensors (1) comprise a solenoid.

29. (New) An apparatus as claimed in claim 16, wherein the semiconductor sensors (1) are CMOS sensors.

Enclosed please find an "Un-Marked Version of the Claims as Amended" including all of the amendments made to the claims 1-20 above as well as new claims 21-29 introduced herein. It is respectfully submitted that new claims 21-29 are commensurate in scope with original claims 1-20 and are supported by the original specification. Please note, additions to the claims are denoted by underlining and deletions from the claims are denoted by bracketing.

REMARKS

It is respectfully requested that the amendments made to the application under Article 34 of the PCT in response to the International Preliminary Examination Report be entered for purposes of the present application.

The specification has been amended to include section headings at appropriate locations and to correct minor grammatical errors.

The claims presently active include claims 1-29, claim 21-29 having been added herein.

The amendments to the claims herein have been made to conform the claims to U.S. practice and have not been made for purposes of patentability. In addition, the claims have been amended to remove multiple dependencies therefrom in order to reduce the filing fee and to more clearly define the invention.

An early and favorable action on the merits is earnestly solicited.

Respectfully submitted,

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Encls.
- Marked-Up Version of the Substitute Specification
- Un-Marked Version of the Substitute Specification
- Un-Marked Version of the Claims as Amended

3/PRTS
09/868051
JC18 Rec'd PCT/PTO 13 JUN 2001

Method and apparatuses for digital imaging

The object of the invention is a digital imaging method, in which method the object being imaged is irradiated and the radiation is detected by means of semiconductor sensors covering an area which is substantially smaller than the image-forming surface.

Further objects of the invention are apparatuses for digital imaging, in which imaging a radiation source is used for irradiating the object being imaged, and semiconductor sensors are used for detecting the radiation, whereby the area covered by the semiconductor sensors is substantially smaller than the image-forming surface. A special object of the invention is a mammography apparatus applying this technology.

Different imaging methods are used for a variety of applications. In imaging applications relating to medicine and biotechnology, among others, x-ray, gamma or beta radiation is typically passed through the object being imaged and further onto an image-forming surface. In recent years, alongside conventional film-based imaging methods digital imaging systems have been developed, the said digital imaging methods using semiconductor sensors such as CCD sensors (Charge Coupled Device) or CMOS sensors (Complementary Metal-Oxide Semiconductor) as the image-forming surface.

Mammography is a typical area of application of digital imaging relating to medical technology which requires a large image-forming surface, typically at least of 18 x 24 cm, and also high resolution. In mammography, strict limits are also set for acceptable exposure to radiation. Mammographic imaging also requires an image-forming surface, whose active area extends on three sides as close to the outer edge of the imaging area as possible, in order that the chest and both armpits can be positioned for imaging in such a way that as much tissue as possible can be imaged.

Semiconductor sensors are typically made of silicon. One disadvantage of this type of sensor is its high price, since with the increase in size of the sensor, the cost of its manufacture per surface area increases exponentially. The manufacture of one semiconductor sensor thus becomes extremely expensive in applications requiring an extensive image-forming surface.

Attempts have been made to avoid the above problem by producing the image-forming surface in a mosaic-like manner from several smaller semiconductor sensors as described, for example, in GB patent publication 2 305 096. In this type of solution, it becomes a problem to obtain a uniform image-forming surface, since one side of a rectangular semiconductor sensor is typically reserved for control couplings. This means that all sides of the sensor cannot be connected to the active area of another sensor, but there will always remain a small gap between them. To compensate for the disadvantages caused by the gaps, various solutions based on lenses or fibre optics can be used, but the disadvantage of lenses is their poor efficiency and the use of fibre optics incurs major additional costs. In some applications, attempts have been made to solve the problem by producing a sensor with a extensive surface by means of a semiconductor technique based on amorphous silicon, but the resolution obtainable in this manner is not sufficient for medical applications requiring a high level of accuracy, as mammography.

A known solution for obtaining a wide image-forming surface is to arrange semiconductor sensors in a chessboard-like fashion in rows and columns so that essentially every other chessboard pattern square comprises a semiconductor sensor in such a way that in one direction, for example parallel to the rows, the sensors extend beyond the chessboard pattern square, and correspondingly in the orthogonal direction, that is, parallel to the columns, there remains a gap between the sensors. In such a case the semiconductor sensor assembly is arranged to be mobile - in a way that the assembly can be moved twice in the direction where there is a gap between the sensors, and the sensor assembly is irradiated in the initial position and after both

moves of the assembly. In this way the area covered by the sensor assembly as a whole - excluding the squares remaining on the edges of the image-forming surface - can be imaged by three exposures.

The problem with the above arrangement is that the sensor assembly has to be moved and stopped for as many as three different exposures. This means that the mechanical structure of the imaging apparatus becomes difficult to implement, the frequent exposures place a load on the radiation source, and the imaging time is prolonged.

To avoid excessive exposure to radiation, in medical applications it is often necessary to arrange for collimation, that is, by means of shadowing, to limit radiation at any time only to the area covered by the sensors. The implementation of collimation then causes a problem area of its own. Since, for example, a typical x-ray source focal spot is not an infinitely small point, but has finite dimensions, for example, of the order 0.3 x 0.3 mm, depending on the structure of the equipment, a half-shadowed area a few millimetres wide is formed at the edges of the radiation field, in which area radiation is incomplete. Because of this, collimation must be planned so that there is a certain amount either of overlap or shortfall at the edge areas, in other words that the areas being imaged either overlap to some extent, or that there is no overlap. However, when the chessboard pattern according to the prior art is used, the overlap causes the radiation dose to double in the lattice-like area, at points even to triple, in the object being imaged, and the shortfall on the other hand forms a lattice-like area in the image being formed, which area has less image information than elsewhere, or where it is completely lacking.

The edge areas of the image-forming surface constitute a further problem, since they cannot be irradiated completely. Empty squares remain on the edges of the image-forming surface, that is, image information is obtained only from the area of every

other square, in which case the edges of the image-forming surface form a kind of castellated pattern.

The aim of the invention is to develop an imaging method and apparatuses for implementing the method in such a way that the foregoing problems can be solved, or at least the disadvantages caused by them can be diminished. These aims are achieved by means of the method and apparatuses, whose characteristic features are defined in the enclosed claims, especially in the characterising parts of the independent claims.

The aims of the invention are achieved especially by arranging the semiconductor sensors so that the entire image-forming surface can be imaged by means of two irradiations, moving the semiconductor sensors only once between the two irradiations.

According to one advantageous embodiment of the invention, the semiconductor sensors are arranged so as to form a bar having essentially the shape of a rectangle, so that the said bar comprises several semiconductor sensors - in either one or two columns. The couplings for controlling the semiconductor sensors, and the other couplings needed, are then preferably situated on one side of the sensor.

According to a further advantageous embodiment of the invention, the said bars are arranged at a distance from one another to form a sensor matrix so that the distance between the bars is at most equal to the width of the active area of the semiconductor sensors of the said bars.

The invention is based on arranging the semiconductor sensors in such a - preferably rectangular - form that by moving the semiconductor sensors from the first position to the second position and by irradiating the object to be imaged in both positions, the entire image-forming surface can be covered, which means that by combining these two images a uniform image of the entire image-forming surface is obtained. By means of a colli-

mator matrix it is possible in both positions to limit radiation only to the area covered by the semiconductor sensors.

An advantage of the method and apparatus according to the invention is the easily implemented mechanical structure as regards both the sensor assembly and collimation. The sensor and collimator assembly can also be made plain to align and of robust structure. As the number of exposures decreases, the thermal stress on the radiation source also decreases, on account of which the cooling of the radiation source does not constitute a significant problem, nor is it necessary to wait for the radiation source to cool, which would slow down imaging work. The time spent on imaging a single object is also reduced since the entire image-forming surface can be covered by just two exposures. Furthermore, the empty squares at the edge of the image-forming surface are eliminated, that is, straight edges are obtained for the image-forming surface, and the disadvantages caused by collimation described above are also less significant than in prior art solutions.

The invention is described in greater detail below with the help of its advantageous embodiments and with reference to the enclosed figures, of which figures

Figure 1 shows, by way of an example, an embodiment of the invention in the context of mammographic imaging,

Figure 2a shows one advantageous structure of the sensor bar,

Figure 2b shows another advantageous structure of the sensor bar,

Figure 3 shows one advantageous structure of the sensor matrix, and

Figure 4 shows one advantageous way of forming a sensor bar.

In Figure 1, the application of the invention is described by way of an example in the context of mammographic imaging, but the invention may obviously also be used for any other corresponding digital imaging. According to Figure 1, the semiconductor sensors 1 are arranged to form essentially rectangular sensor bars 2, which sensor bars 2 form a mobile sensor matrix 3. The sensor bars 2 are arranged in the sensor matrix 3 in a fixed position with respect to one another, so that between the sensor bars 2 remains a vacant area narrower than a sensor bar 2. Collimation is carried out by means of essentially rectangular collimators 4, which then form a mobile collimator matrix 5, in which the collimators 4 are placed in a fixed position with respect to one another. The collimator matrix 5 is positioned for imaging in such a way that the collimators 4 shadow the vacant areas between the sensor bars 2 of the sensor matrix 3, as seen from the radiation source 6, in which case no radiation will be focused on these areas. The collimator construction can be situated, as in Figure 1, either in the immediate vicinity of the object being imaged or at a distance from it - even in the immediate vicinity of the radiation source. The object 7 being imaged, in mammography typically the breast, is placed between the collimator matrix 5 and the sensor matrix 3 and the object is irradiated with the radiation from the radiation source 6. The semiconductor sensors 1 detect the radiation they receive, on the basis of which digital image information is formed with the help of a sample and hold circuit 8 and an analog-to-digital converter 9. If necessary, the image information can be edited further, for example, to compensate for dark current and possible non-linearities. The image information is transmitted further either to processing means 10 or memory means 11. After this, and with the object 7 being imaged still remaining in the same position, the sensor matrix 3 is moved in the sideways direction so that the sensor bars 2 will cover essentially the same areas where the vacant areas between sensor bars 2 were situated before the move. In mammography, the object 7 being imaged, that is, the breast, is kept in place with the help of pressing means (not shown). The collimator matrix 5 is moved correspondingly so that the collimators 4 then shadow

the vacant areas between the sensor bars 2 conforming to the new position of the sensor matrix 3. The object 7 being imaged is irradiated for a second time with the new settings of the sensor matrix 3 and collimator matrix 5, and the image information formed on the basis of the second irradiation is combined with the image information formed on the basis of the first irradiation in the processing means 10. By means of two irradiations, therefore, an image of the entire image-forming surface can be obtained.

With the solution described above considerable advantages are achieved with respect to the prior art. The mechanical structure according to the invention is easier to implement as regards both the sensor matrix and collimation. The sensor matrix formed of rectangular sensor bars is plain to align and has a robust structure. The collimator matrix is also easy to construct and it is easy to align with respect to the sensor matrix. Furthermore, as the object being imaged is only irradiated twice, the load on the radiation source decreases, which prolongs its service life and speeds up the imaging work, because the need to cool the radiation source is lessened, and the time spent on imaging a single object is also shortened.

Compared with a uniform image-forming surface, the arrangement relating to the invention requires only half of the active surface area of the semiconductor sensors. On the other hand, when using, for example, CMOS sensors, the invention can, if so desired, be realised so that no arrangement based on lenses or fibre optics will be needed to compensate for the gaps between the semiconductor sensors.

As the sensor and collimator matrix are only moved once, the accuracy of a move carried out in only one direction needs to be looked after. It is, therefore, possible to dimension and align the collimator matrix in such a way that the overlap of the areas being irradiated is significantly reduced, and thus the disadvantages of collimation are diminished in comparison to known solutions.

The final formation of a digital image can be carried out by connecting the imaging equipment with a computer, in which case the computer's memory and processing means can be utilised. The processing means 10 relating to Figure 1 can also be realised, for example, by a dedicated Application Specific Integrated Circuit (ASIC), to which are connected memory means 11, for example, a FLASH memory. The formation of final image information is known as such to a person skilled in the art, and its more detailed description is not necessary for the implementation of the invention.

According to one advantageous embodiment of the invention, the sensor bars 2 to be placed in the sensor matrix 3 are formed of semiconductor sensors 1, which are substantially smaller than the sensor bars 2. Figures 2a and 2b show two advantageous ways of arranging the semiconductor sensors 1 to form a sensor bar 2. In both figures, the sensor bar 2 comprises semiconductor sensors 1a, 1b, ..., which are arranged to form a rectangular sensor bar 2. A typical semiconductor sensor 1n comprises an active area A, which is used for detecting the radiation received, and a coupling area K, through which the control signals of the sensor 1n and the charge readout, that is, in this case the collection of image information, are transmitted. In a semiconductor 1n, at least one side is typically reserved for the coupling area K, and thus the semiconductor sensor 1n can advantageously be connected to another semiconductor sensor 1n on three sides, as shown in Figure 2b, if it is desirable that the active areas of the sensors form a uniform surface. The sensor bar 2 can thus be formed of either one (1 x N) or two (2 x N) columns of semiconductor sensors 1n. The distance between sensor bars 2 in the sensor matrix 3 is determined on the basis of the width #A of the active area A of the semiconductor sensors 1 used, in other words, the maximum distance between the sensor bars 2 can, in the case of single column sensor bars 2, equal the width #A of A (Figure 3), or in the case of sensor bars with two columns, 2 x the width of A, that is, 2 x #A.

When the sensor bar 2 is formed of semiconductor sensors 1n which are substantially smaller than the sensor bar 2, no large and therefore expensive semiconductor sensors are required. Further cost savings ensue from the fact that if a single semiconductor sensor 1n is damaged, it can be replaced without having to replace the entire sensor bar 2.

Figure 3 shows an advantageous manner of arranging the sensor bars 2 according to the invention, so that the image-forming surface is made as large as possible and the edges of the image-forming surface become uniform. The sensor bars 2 consist of one column (1 x N) of semiconductor sensors 1n, in which case the outermost sensor bars 2 are placed so that the coupling area K of the semiconductor sensors 1n is placed towards the inside of the sensor matrix 3. The image-forming surface will then extend over the entire area covered by the sensor matrix 3 and the so-called castellated pattern will not be formed on the edges of the image-forming surface. The positioning of the coupling areas of the sensor bars 2 inside the sensor matrix 3 may be selected freely, provided that the vacant areas between the sensor bars are correctly dimensioned. The sensor bars 2 may obviously also be formed of two columns (2 x N) of semiconductor sensors 1n, but if the outermost sensor bars 2 are also formed in this manner, the active area of the sensor matrix 3 cannot be made to extend sideways all the way to the edges of the image-forming surface.

An application of the invention may obviously also be envisaged where a sensor matrix is constructed of different types of sensor bars, that is, for example sensor bars with active areas of varying widths, one or two columns, having coupling areas on opposite sides and/or even sensor bars based on different technologies. However, and especially if this type of sensor bar is used in applications where radiation has to be limited to the sensor matrix area, some of the advantages obtained with the invention may be lost.

According to one advantageous embodiment of the invention, the movements of the collimator matrix and sensor matrix are not connected to each other, but each matrix is moved separately. This is preferably done by first moving the sensor matrix into its new position and then aligning the collimator matrix according to the sensor matrix. The invention may, however, naturally also be implemented so that the movements of the collimator matrix and sensor matrix are synchronised.

The movement of the sensors and/or collimators may be carried out, for example, by means of solenoids or separate servomotors. The use of a solenoid is especially recommended since it is an economical, accurate and reliable component. The invention particularly makes it possible to use solenoids since, according to the invention, the sensors and/or collimators need to be moved only between two positions.

According to one advantageous embodiment of the invention, the semiconductor sensors are CMOS sensors based on direct detection of radiation, the said sensors having certain advantages compared with conventional semiconductor sensors. With the CMOS sensors improved resolution is achieved compared with conventional semiconductor sensors and due to the parallel bus type data transfer, they enable more rapid transfer of image information. CMOS technology is the most widely applied semiconductor technology, which means that the availability of CMOS circuits is good, and their production costs will fall as the technology develops.

Figure 4 shows an advantageous way, in accordance with the invention, of forming the sensor bar of CMOS sensors. The CMOS sensors 13, 14,... are connected to a preferably rectangular radiation detector 12 with substantially the same external dimensions as the bar. The detector 12 is preferably made of doped silicon (Si) or a cadmium zinc telluride compound (CdZnTe). Between the top and bottom surfaces of the detector is generated a biasing voltage Ur, by means of which the charge generated by the radiation is collected to the nearest pixel.

The charge generated is transmitted to the CMOS sensors 13, 14, …, which are connected to the detector 12, preferably by means of microscopic ball conductors, that is, by means of so-called bump bonding. In the coupling area of the CMOS sensors, control signals can be fed to the sensors and the radiation detected can be read by means of pins at the end of the sensors, for the purpose of forming image information. The detection of radiation by means of CMOS sensors is known as such to a person skilled in the art.

In accordance with the invention, semiconductor sensors known as such, which are based on the use of lenses or fibre optics, can obviously also be used, in which case the coupling areas can also be located in the three-dimensional structure of the sensor on a surface that allows the whole width of the sensor to be utilised as an active radiation-detecting area. This means, however, that some of the advantages achieved with the invention are at the same time lost.

Although the invention is described above by way of an example in the context of mammography, it can obviously also be used in connection with any other similar imaging application. In accordance with the invention, any radiation that is detectable by semiconductor sensors can be used.

The invention is particularly useful in imaging applications relating to medical technology, where x-ray or gamma radiation is typically used, and in biotechnical applications where beta radiation is typically used. The invention is furthermore applicable to industrial testing and quality control methods utilising radioscopy.

It is obvious to a person skilled in the art that as technology develops, the basic idea of the invention can be implemented in various ways, which means that its different embodiments are not limited to the foregoing examples, but may vary within the scope of protection defined in the enclosed claims.

Un-Marked Version of the Claims as Amended 783.1005

Claims

1. (Amended) A digital imaging method, in which method the object being imaged is irradiated and the radiation is detected by means of semiconductor sensors, which comprise an active area, and in their three-dimensional structure an area or areas for control couplings, whereby the area covered by the semiconductor sensors is substantially smaller than the image-forming surface of the object being imaged, said method comprising the steps of:

irradiating the object being imaged a first time;

moving the semiconductor sensors to a new position; and

irradiating the object being imaged a second time, wherein the sensors are arranged to cover an image-forming surface so that the entire image-forming surface can be imaged.

2. (Amended) An imaging method as claimed in claim 1, wherein a coupling area of the semiconductor sensor is arranged on one side of the semiconductor sensor.

3. (Amended) An imaging method as claimed in claim 1 wherein the semiconductor sensors are arranged to form rectangular bars.

4. (Amended) An imaging method as claimed in claim 3, wherein said bars are arranged to be formed of one column (1 x N) of semiconductor sensors.

5. (Amended) An imaging method as claimed in claim 4, wherein the semiconductor sensors are arranged in the bars so that the coupling areas of said semiconductor sensors located on one side of each bar.

6. (Amended) An imaging method as claimed in claim 3, wherein the bars are arranged to form a sensor matrix, and wherein the bars are arranged at a distance from one another so that the said distance between the bars is at most equal to the width of an active area formed by the semiconductor sensors in the bars.

7. (Amended) An imaging method as claimed in claim 6, wherein outermost bars of the sensor matrix are arranged so that an active area of the outermost bars comprises the outer edges of the image-forming surface.

8. (Amended) An imaging method as claimed in claim 3, wherein said bars are arranged to comprise two columns (2 x N) of semiconductor sensors.

9. (Amended) An imaging method as claimed in claim 8, wherein the semiconductor sensors are arranged in the bars so that coupling areas of the semiconductor sensors are located on two sides of each bar.

10. (Amended) An imaging method as claimed in claim 8 wherein the bars are arranged to form a sensor matrix, and wherein the bars are arranged at a distance from one another so that the distance is at most equal to the width of an active area formed by the

semiconductor sensors in the bars.

11. (Amended) An imaging method as claimed in claim 1, further comprising the step of:

limiting the radiation to an area covered by the sensors, for which limiting function a suitable collimator construction is used.

12. (Amended) An imaging method as claimed in claim 11, further comprising the step of:

separately moving the collimator construction and the sensors.

13. (Amended) An imaging method as claimed in claim 11, wherein the movement of at least one of the collimator construction and the sensors is carried out by means of solenoids.

14. (Amended) An imaging method as claimed in any of the claims 1 wherein CMOS sensors are used as the semiconductor sensors.

15. (Amended) An imaging method as claimed in claim 1, wherein the method is used in the context of mammographic imaging.

16. (Amended) An apparatus for digital imaging, in which imaging a radiation source is used for irradiating an object to be imaged and semiconductor sensors are used for detecting the radiation, said apparatus comprising:

semiconductor sensors (1) having an active area (A), and in their three-dimensional structure, an area or areas for control couplings (K), the area covered by the said semiconductor sensors (1) being substantially smaller than the image-forming surface, and

means for moving the semiconductor sensors (1) to a new position between two irradiations, in which apparatus the semiconductor sensors (1) and the means for moving the semiconductor sensors are arranged so that the area covered by the semiconductor sensors (1) in their initial position prior to the move, combined with the area covered by the semiconductor sensors (1) in their position after the move, cover the entire image-forming surface.

17. (Amended) An apparatus as claimed in claim 16, the area for control couplings (K) of the semiconductor sensor (1) are arranged on one side of the semiconductor sensor (1).

18. (Amended) An apparatus as claimed in claim 16 wherein several semiconductor sensors (1n) are arranged to form rectangular bars (2).

19. (Amended) An apparatus as claimed in claim 18, wherein the bars (2) comprise one column (1 x N) of semiconductor sensors (1n).

20. (Amended) An apparatus as claimed in claim 19, wherein the semiconductor sensors (1n) are arranged in the bars (2) so that the area of control coupling(K) is located on one

side of each bar (2).

Please add the following new claims.

21. (New) An apparatus as claimed in claim 18, wherein the bars (2) form a sensor matrix (3) in which the bars (2) are arranged at a distance (A#) from one another, in such a way that the distance (A#) is at most equal to the width of an active area (A) formed by the semiconductor sensors (1n) in the bars (2).

22. (New) An apparatus as claimed in claim 21, wherein the active area (A) of the outermost bars (2) of the sensor matrix (3) comprise the outer edges of the image-forming surface.

23. (New) An apparatus as claimed in claim 18, wherein the bars (2) comprise two columns (2 x N) of semiconductor sensors (1n).

24. (New) An apparatus as claimed in claim 23, wherein the semiconductor sensors (1n) are arranged in each bar (2) in such a way that the area for control coupling (K) for each semiconductor sensor (1n) is located on two sides of each bar (2).

25. (New) An apparatus as claimed in claim 23 wherein the bars (2) form a sensor matrix (3) in which the bars (2) are arranged at a distance (A#) from one another, in such a way that the distance (A#) is at most equal to the width of an active area (A) formed by the semiconductor sensors (1n) in the bars (2).

26. (New) An apparatus as claimed in claim 16, further comprising:

means for limiting radiation to an area covered by the semiconductor sensors (1), the means for limiting radiation comprising a suitable collimator construction (4, 5).

27. (New) An apparatus as claimed in claim 26, further comprising:

means for moving the collimator construction (4, 5), and

means for moving the semiconductor sensors (1).

28. (New) An apparatus as claimed in claim 27, wherein said means for moving at least one of the collimators (4, 5) and the sensors (1) comprise a solenoid.

29. (New) An apparatus as claimed in claim 16, wherein the semiconductor sensors (1) are CMOS sensors.

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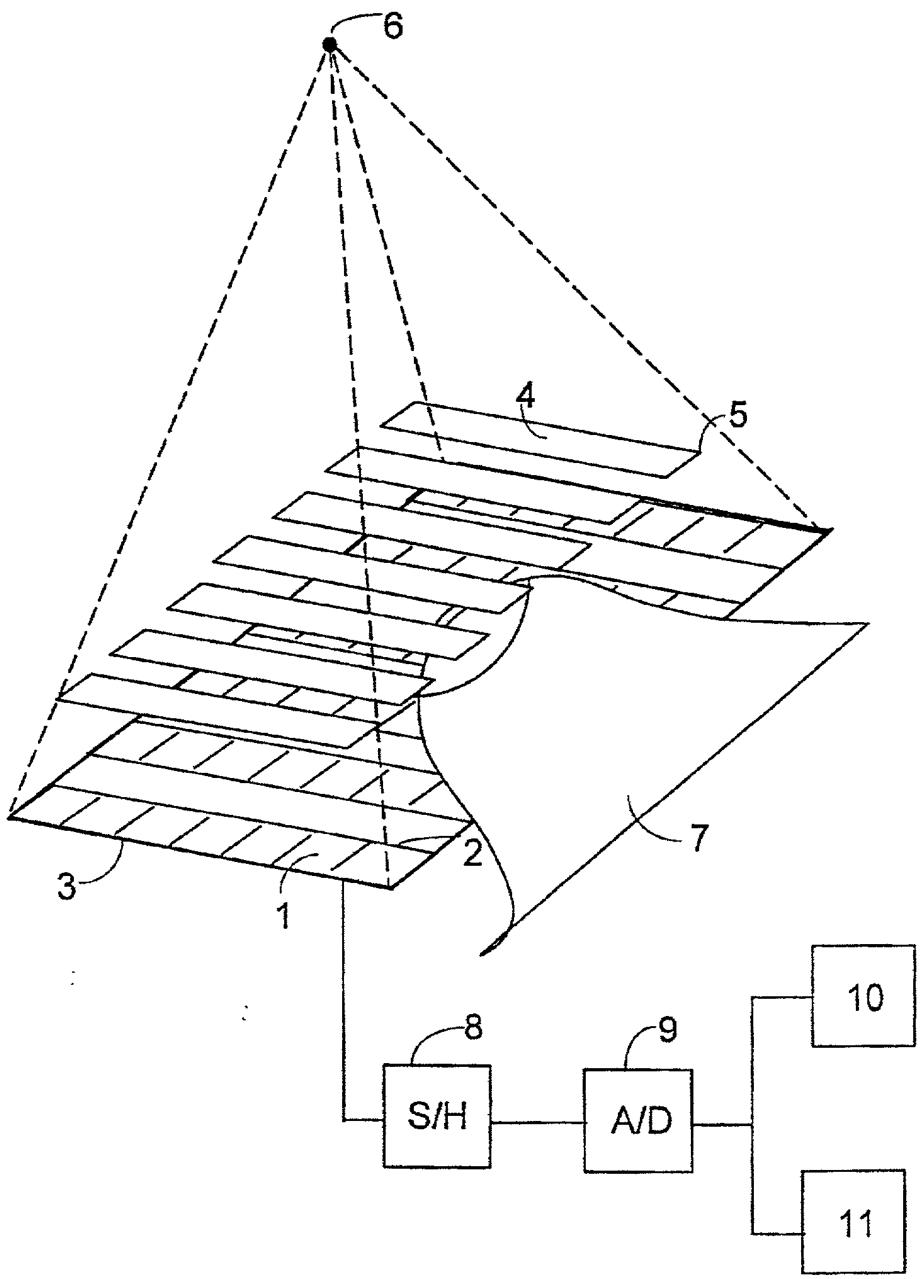

FIG. 1

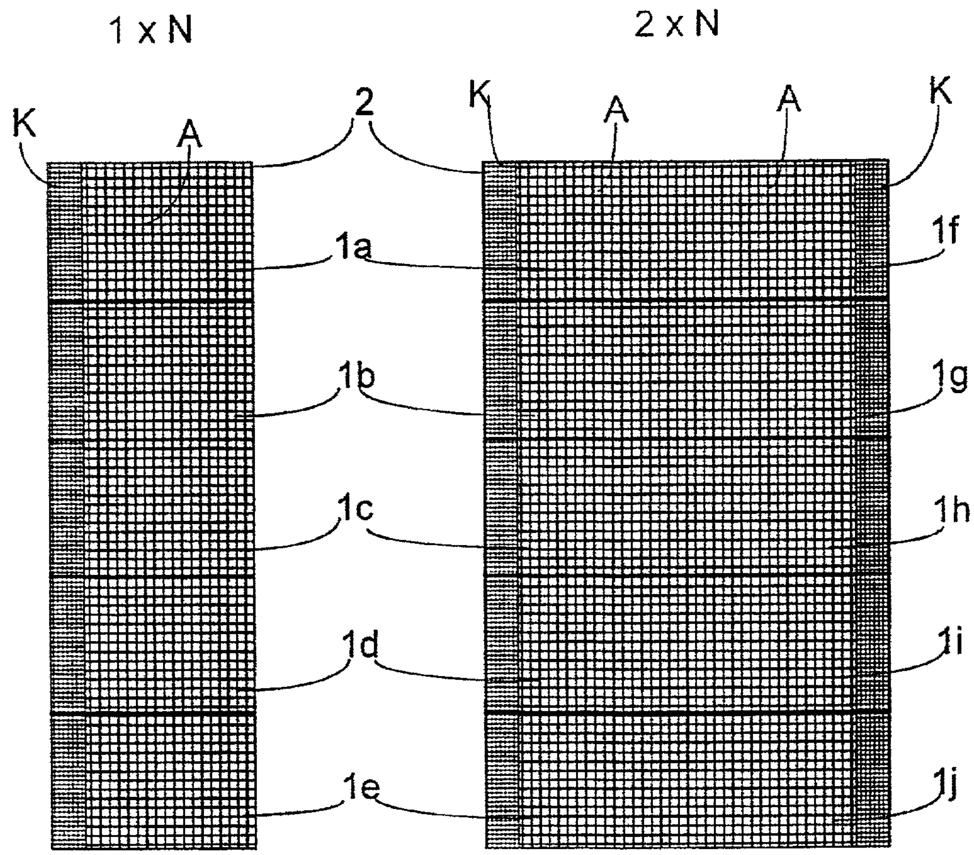

FIG. 2a FIG. 2b

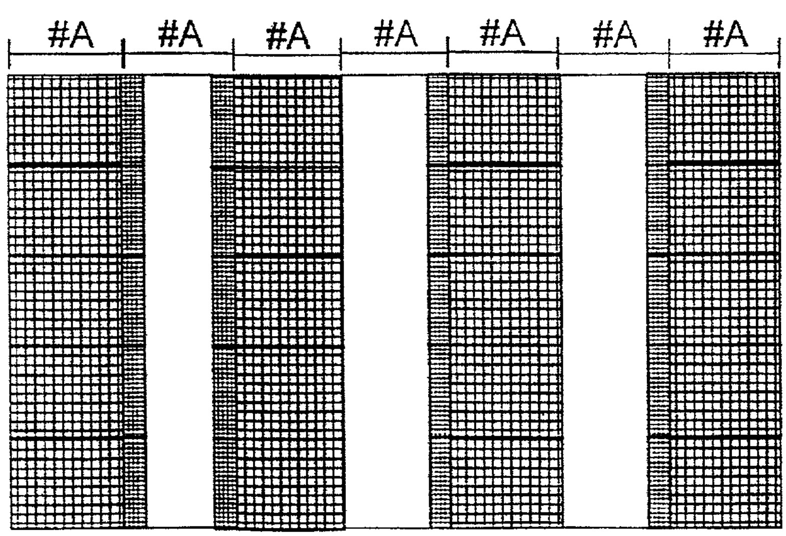

FIG. 3

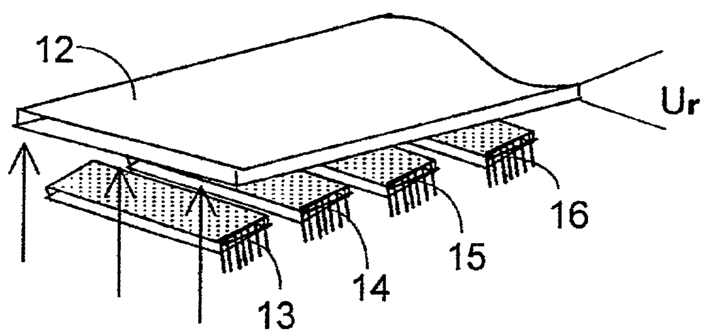

FIG. 4

DECLARATION AND POWER OF ATTORNEY FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

[X] Declaration submitted with initial filing
[ ] Declaration submitted after initial filing (surcharge (37 CFR 1.6(e) required))

First Named Inventor: Kustaa HYHOLM

COMPLETE IF KNOWN:

Application Number:

Filing Date:

Group Art Unit:

Examiner Name:

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name. I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

METHOD AND APPARATUSES FOR DIGITAL IMAGING
(Title of the Invention)

the specification of which
[X] is attached hereto
OR
[ ] was filed on (MM/DD/YY) __________ as United States Application Number or PCT International Application Number __________ and was amended on (MM/DD/YY) __________ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above. I acknowledge the duty to disclose information which is material to patentability of this application as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT International application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YY)	Priority Not Claimed	Certified Copy Attached? Yes	No
982704	Finland	December 14, 1998			X

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YY)

I hereby claim the benefit under 35 U.S.C. 120 of any United States application(s), or 365(c) of any PCT International application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application or PCT Parent Number	Parent Filing Date (MM/DD/YY)	Parent Patent Number (if applicable)
PCT/FI99/01028	December 13, 1999	

As a named inventor, I hereby appoint the following registered practitioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

[X] Customer Number 21831

Direct all correspondence to:

[X] Customer Number 21831

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

NAME OF SOLE OR FIRST INVENTOR:

Given Name (first and middle [if any]) Family Name or Surname

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Inventor's Signature ____ Date 21.5.01

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